DESIGN AND FABRICATION OF SOLAR ELECTRICAL VEHICLE SYSTEM

M.V.RAMESH[1], G.VIJAY KUMAR[2], G.DIWAKAR[3]

Abstract—With an increasing concerns on our environment, there is a fast growing interest in Electric Vehicle for all stakeholders and the development of electric vehicle technology has taken on an accelerated pace. The design and construction of Electric Vehicle is a pressing need for researchers to develop advanced electric vehicle system. In this paper, an overview for the fabrication of Electric Vehicle is presented, with emphasis on mechanical topologies and drive operations. Then, three major research directions of the Electric Vehicle systems are elaborated, namely, the design and building of chasis, axle, steering structure and erection of solar system for Electric Vehicle system. The Permanent Magnet Brushless DC Motor (PMBLDCM) is the main system for driving Electric Vehicle. PMBLDCM is used as electric variable-transmission system.

Index Terms—BLDC motor,Chassis, Design, Electric Vehicle,Fabrication, ANSYS.

1 INTRODUCTION

Unlike vehicles with combustion engines, electric vehicles do not produce exhaust gases during operation. This alone makes electric vehicles more environment friendly than vehicles with conventional technology. However, the electrical energy for charging the vehicle does have to be produced from renewable sources. Electric drive motors run quieter than internal-combustion engines. The noise emissions from electric vehicles are very low. At high speeds, the rolling noise from the tires is the loudest sound. Electric vehicles produce no harmful emissions or greenhouse gases while driving. If the high-voltage battery is charged from renewable energy sources, an electric vehicle can be run CO_2 -free. In the near future, if particularly badly congested town centres are turned into zero-emissions zones, we will only be able to drive through them with high-voltage vehicles. The electric drive motor is very robust and requires little maintenance. It is only subject to minor mechanical wear. Electric drive motors have a high degree of efficiency of up to 96% compared to internal-combustion engines that have an efficiency of 35–40%.

Electric drive motors have excellent torque and output characteristics. They develop maximum torque from standstill position. This allows an electric vehicle to accelerate considerably faster than a vehicle with an internal combustion engine producing the same output. The drive train design is simpler because vehicle components like the transmission, clutch, mufflers, particulate filters, fuel tank, starter, alternator and spark plugs are not required. When the vehicle is braked, the motor can also be used as an alternator that produces electricity and charges the battery (regenerative braking). The high-voltage battery can be charged at home or by running. The energy is only supplied when the user needs it. Compared with conventional vehicles, the electric drive motor never runs when the vehicle stops at a red light. The electric drive motor is highly efficient particularly in lines and bumper-to-bumper traffic. Apart from the reduction gearbox on the electric drive motor, the electric vehicle does not require any lubricating oil.

The paper is organized as follows: Section 2 explains about Design calculations, Section 3 discusses about the mechanical design, Section 4 explains about the driving system of EV. In Section 5 , the design and fabrication results are presented in detail and Section 6 highlights the conclusions.

2 DESIGN CALCULATIONS

2.1 Load Calculations

Estimation of Electrical Vehicle Weight, Assuming a motor speed of 3000 rpm and power of 3KW and Maximum velocity of 30km/hr.

$$\text{Power} = \frac{2\pi NT}{60} \quad \text{-- Equation (1)}$$

$$T = \frac{60*P}{2\pi*3000}$$

$$= \frac{60*3*750}{2*\pi*3000}$$

=7.16 N-m.

Velocity of the vehicle = 30km/hr

$$= 30*\frac{5}{18}.$$

= 8.33 m/s

Velocity (V) = R*ω. -----Equation (2)

ω = V/R, Here R is radius of wheel= 15cm

$$\omega = \frac{8.33}{0.15}$$

ω =55.55 m²/s

ω = axle speed

$$\omega = \frac{2*\pi*N}{60} \quad \text{-------Equation (3)}$$

$$55.55 = \frac{2*\pi*N}{60}$$

$$N = \frac{55.55*60}{2\pi}$$

Motor Speed N = 530 rpm

$$\text{Available torque on shaft } T = \frac{60*3*750}{2\pi*530}$$

T= 40.53 N-m

With 30% loss of torque, T=40.53*0.7 =28.37 N-m

$$\text{Force } F=\frac{T}{R_s} \quad \text{---------Equation (4)}$$

$$F=\frac{28.37}{0.15}$$

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F = 189 N.

$$\text{Weight (W)} = \frac{F}{\mu} \text{ --------Equation (5)}$$

Assuming rolling friction between vehicle tire and road as 0.02

$$W = \frac{189}{0.02}$$

W = 9456.66 N.

W = 945.66 kg.

Without loss of torque, force is,

$$F = \frac{T}{R_s} \text{ -----------Equation (6)}$$

$$= \frac{40.53}{0.15}$$

F = 270.2 N

$$\text{Weight (w)} = \frac{F}{\mu} \text{ ---------Equation (7)}$$

$$W = \frac{270.2}{0.02}$$

W= 13510 N = 1351kg.

Similarly the calculation is made for 25%, 20% and 10% loss of torque and results are tabulated in the table 2.1.

Table 2.1.Chassis weight comparison table with %loss of torque.

Loss of torque	**Force (N)**	**Weight (kg)**
30%	189.13	945.66
25%	216.16	1080.8
20%	229.66	1148.35
10%	243.18	1215.9

2.2 Pressure Load

Gross vehicle weight (G.V.W) = 1000kg. This load (G.V.W) is applied in the form of pressure.

Hence the total area of application of load as calculated from chassis dimensions = 5676.9 cm^2.

Hence the total load to be applied = 1000*9.81= 9810N.

Pressure to be applied = load/area =9810/5676

P= 1.73 N/cm^2 .

3. MECHANICAL DESIGN

Chassis usually denotes the basic frame that decides the overall shape of the vehicle. It holds the important components of the vehicle. The chassis of electrical vehicle being changed is of ladder frame type which has two side members or longitudinal members of C- cross section and five transverse members called cross members with same cross section. The chassis has been modeled in pro-e Wildfire 2.0 and Analysis was done using ANSYS.

3.1. TYPES OF CHASSIS:

Ladder Chassis: Ladder chassis is considered to be one of the oldest forms of automotive chassis that is still used by most of the SUVs till today. As its name connotes, ladder c resembles a shape of a ladder having two longitudinal rails inter linked by several lateral and cross braces.

Monocoque Chassis: Monocoque Chassis is a one-piece structure that prescribes the overall shape of a vehicle. This type of automotive chassis is manufactured by welding floor pan and other pieces together. Since Monocoque chassis is cost effective and suitable for robotized production, most of the vehicles today make use of steel plated Monocoque chassis.

Backbone Chassis: Backbone chassis has a rectangular tube like backbone, usually made up of glass fiber that is used for joining front and rear axle together. This type of automotive chassis or automobile chassis is strong and powerful enough to provide support smaller sports car. Backbone chassis is easy to make and cost effective.

3.2 Problem Specifications

The objective of the present work is to design and analyze the cast iron chassis frame with two different cross sections. The chassis model was created in pro-e software and it is imported into ANSYS, static analysis is performed. Original TATA ACE ZIP chassis is shown in Fig. 2.1

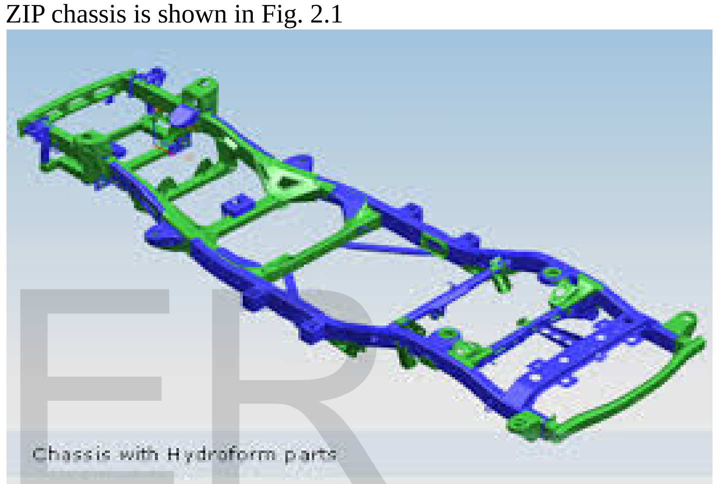

Fig. 3.1: Tata ACE ZIP chassis

3.3 Structural Analysis Of Electrical Vehicle Chassis for I-Section

Dimensions of electrical vehicle chassis are taken from Tata ace as shown in the fig 3.1. 3-D model of chassis is used for analysis in ANSYS. The loading conditions are assumed to be static. The element chosen is Solid 186, a higher order 3-D 20-node solid element that exhibit quadratic placement behavior. The element is described by 20 nodes having three degree of freedom per node: translations in the nodal X, Y, and Z direction. The element supports plasticity, hyper elasticity, creep, stress stiffening, larger deflection, and large stain capabilities.

3.3.1 CHASSIS MODEL DIMENSIONS

Chassis was model based on the Tata ace zip chassis dimensions, from that dimensions based on the project requirement the values are taken as ration down from the original values of Tata ace zip. Based on the ratio following vales are taken as,

Total length of the chassis =300cm

Total width of the chassis =130cm

And in this chassis design, chassis have 5 cross members and three lateral members.

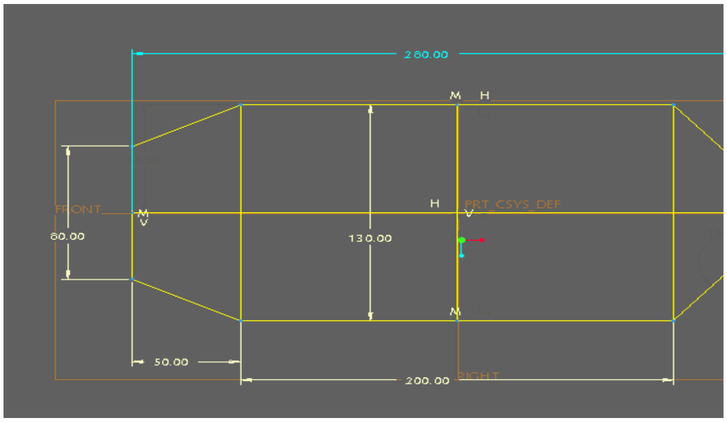

Fig 3.2: Line diagram for C section chassis.

Stress analysis is done using ANSYS, 20 noded solid 186 element was used. First boundary condition is fixed at 1/3 of 100 cm i.e.33.3 cm from first cross member of chassis back side as shown in Fig. 3.1 and second boundary condition is based on the leaf spring design that is the total length of the leaf spring 50cm,this is same at another side of wheel arrangement. And final fixed node is at middle node of the first cross member from front side. The pressure load of 1.73 N/cm^2 is applied on top of the surface area.

3.3.2 STRUCTURAL ANALYSIS FOR I-SECTION CHASSIS

I section chassis frame forms the backbone of a heavy vehicle, its principle function is to safely carry the maximum load for all designed operating conditions. The processes of analyzing for I cross section chassis is same like L-type cross section chassis. Figure 3.2 represents the I-cross section line diagram with same dimensions given to the L angular cross section.

Following are the I-type cross section dimensions taken for chassis design and analysis.

Width =3.81cm.

Height =7.62 cm.

Thickness =0.6 cm.

The above values are taken based on the vehicle weight consideration and availability of cross section dimensions in the market.

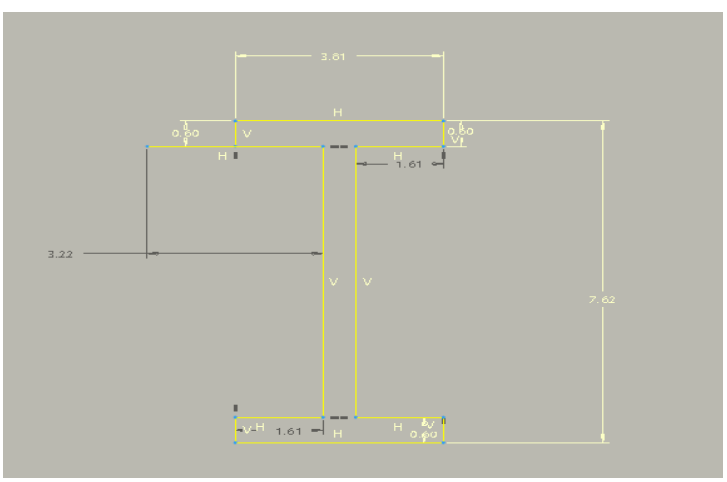

Fig 3.3: I-type cross Section with dimension

3.3.3 Meshing

Meshing is the process used to fill the solid model with nodes and elements, i.e, to create the FEA modal. Meshing is done with 20 noded solid 186 element and performing the meshing processes. Meshing is consider as a area mesh, areas are meshed with edge length of 3. Meshing model helps to get accurate results in the ANSYS.

3.3.4 Load and Boundary conditions

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by steady loads that do not induce significant inertia and damping effects. Boundary condition involves application of load and defining constraints in the model. In this project Model is fixed in all degrees of freedom.The boundary conditions are fixed at supports and pressure load of 1.73 N/cm^2 are applied on the chassis areas..

3.3.5. Deformed shape

After completion of applying boundary conditions and pressure load of 1.73N/cm^2 on chassis area.

3.3.6 Stress intensity

Stress Intensity Factor, K, is used in fracture mechanics to more accurately predict the stress state ("stress intensity") near the tip of a crack caused by a remote load or residual stresses. When this stress state becomes critical a small crack grows ("extends") and the material fails.

3.3.7 Von mises stresses

Von Mises stress is considered to be a safe haven for design engineers. Using this information an engineer can say his design will fail, if the maximum value of Von Mises stress induced in the material is more than strength of the material. It works well for most cases, especially when the material is ductile in nature. Fig.3.7 shows the von mises stresses values.

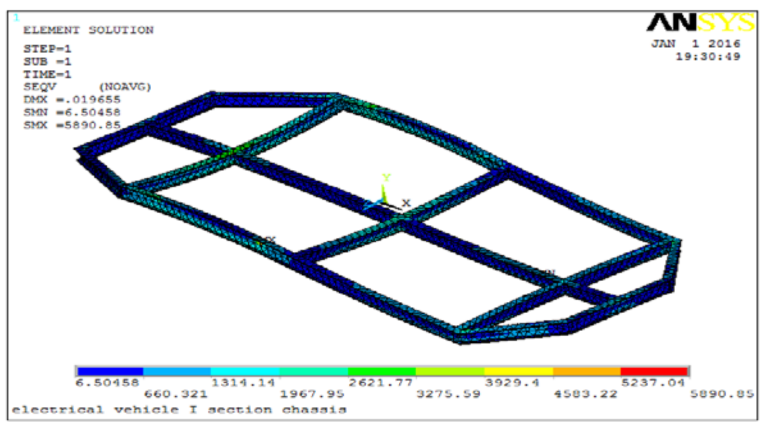

Fig .3.4: Von mises stresses.

3.4 Structural Analysis Of Electrical Vehicle Chassis For C-Type Cross Section

Now a day's C-type cross section chassis are used in most of the auto mobile chassis. Static analysis is done as like above two section.Structural analysis is done using ANSYS for C section chassis, line diagram with dimensions is shown in figure 4.1.

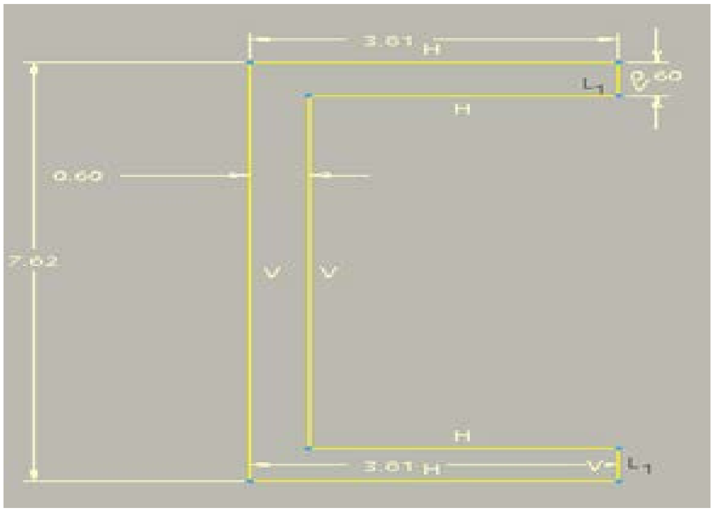

Fig. 3.5: C-type cross-section of chassis

3.4.1. Solid model designed in pro-e software

Based on the cross section and dimensions the chassis was designed in pro-e software as shown Fig.4.2.

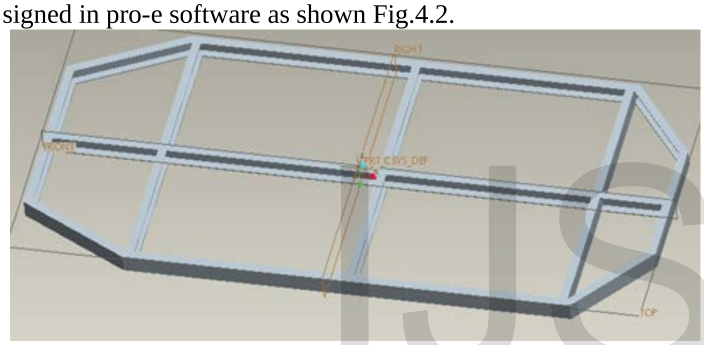

Fig. 3.6: Chassis model in PRO-E

3.4.2. Meshed model and boundary condition

Meshing model and boundary conditions are same as mentioned in Fig.3.4 and Fig.4.3 shows model for C section chassis. This meshing processes is same as earlier as described for I cross section chassis.

3.4.3. Deformed shape

Chassis was deformed when pressure load of 1.73 N/cm^2 applied. Pressure load is same for this C section chassis also because the cross section dimensions are same for two cross section chassis there by area also same as 5676.9. So when pressure load is applied.

3.4.4. C-type cross section Stress intensity

Below Fig.4.6 shows the stress intensity. Load and boundary conditions are same as mentioned above. The value of stress intensity is 62.58 Mpa for this chassis.

3.4.5. C-type cross section von mises stresses

Von mises stresses values are obtained based on chassis dimensions, pressure load, surface area and boundary conditions. The value of von mises stresses for C section chassis is 58.60 Mpa shown in Fig.4.6

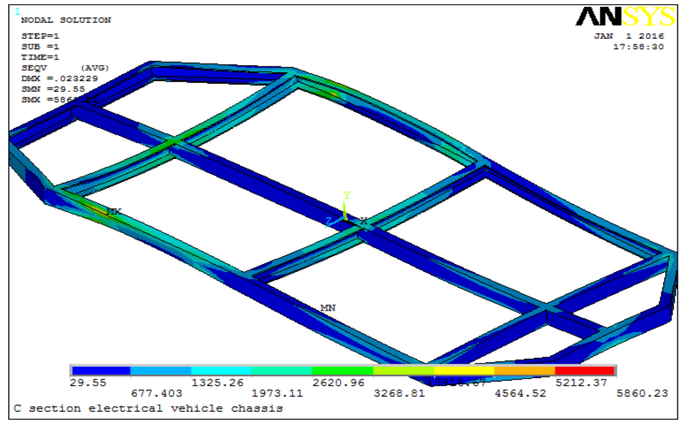

Fig. 3.7: C-type cross section von mises stresses

4DRIVE SYSTEM

4.1 GEARS

Agearboxisadeviceforconvertingthespeedofashaftfromonespeedtoanother. Intheprocessthetorqueisalsochanged.Thiscanbedonewithpulleyandchain drives but gears have advantages over these system. A good example is that ofwinch in which a motor with a high speed and low torque is geared down to turn the drum at a low speed with a large torque. Similarly, a marine engine may use a reductiongear boxtoreducethespeedoftheenginetothatofthepropeller.Otherexamplesare motor vehicles, lathes, drills and many more. Figure 4.1 shows a typical winchthat has a reduction gear box built inside thedrum.

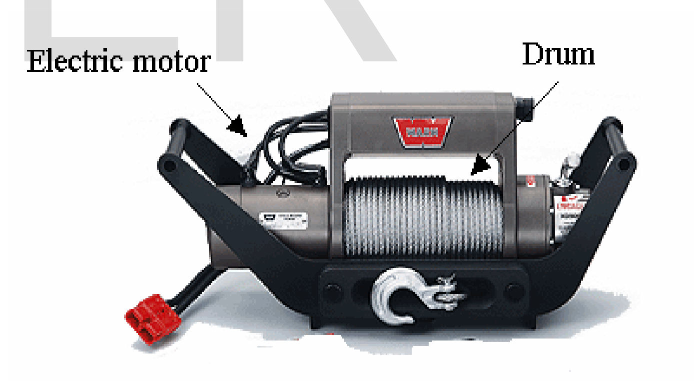

Fig. 4.1:winch

Gears are wheels which mesh with each other through interlocking teeth. Rotationof one wheel produces rotation of the other with no slip between them. The shape ofthe gear teeth is important in order to produce a smooth transfer of the motion. Themost common shape is the INVOLUTE gear form but it is not our task to study thishere. Thedesignofthegearteethalsoaffectstherelativepositionofonegeartoanother. Forexamplebevelledgearsallowtheaxisofonegeartobeinclinedtotheaxisof another.Wormgearsconvertthemotionthrough90^{o}andsoon.Thedesign also affects the friction present in thetransfer.

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Fig. 4.2: Different types of gears

4.2 Differential Assembly

Torque is supplied from the engine, via the transmission, to a drive shaft which runs to the final drive unit that contains the differential. A spiral bevel pinion gear takes its drive from the end of the propeller shaft, and is encased within the housing of the final drive unit. This meshes with the large spiral bevel ring gear, known as the crown wheel. The crown wheel and pinion may mesh in hypoid orientation.. The crown wheel gear is attached to the differential carrier or cage, which contains the 'sun' and 'planet' wheels or gears, which are a cluster of four opposed bevel gears in perpendicular plane, so each bevel gear meshes with two neighbours, and rotates counter to the third, that it faces and does not mesh with. The two sun wheel gears are aligned on the same axis as the crown wheel gear, and drive the axle half shafts connected to the vehicle's driven wheels. The other two planet gears are aligned on a perpendicular axis which changes orientation with the ring gear's rotation. If the left side gear encounters resistance, the planet gear spins as well as revolving, allowing the left side gear to slow down, with an equal speeding up of the right side gear.

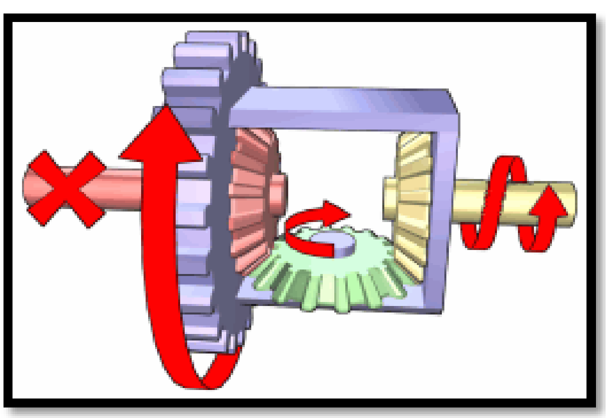

Fig. 4.3:**Differential Assembly**

4.3 Universal Joint

On the structure and function of the universal joint is a bit like human limbs joints, it allows the Angle between the connected parts changes within a certain range. For, adapt to and meet the power generated by jumping up and down when the car running changes caused by the Angle, front drive cars drive axle, axle shaft is connected to a common universal joint between wheel and axle. But due to the restrictions on the size of the axial, Angle but also is bigger, a single universal joint cannot make the output shaft and the shaft into the shaft of the instantaneous angular velocity are equal, easy to cause vibration, adding parts damaged, and generate a lot of noise, so widely used in a variety of patterned constant speed universal joint. In before the drive motor vehicles, each half shaft with two patterned constant speed universal joint, the universal joint near the transaxle is half shaft inside of the universal joint, near the lateral axle is half shaft universal joint. The rear drive vehicle, engine, clutch and transmission as a whole is installed on the frame, and connected to the frame, drive axle by elastic suspension, there is a distance between the need for connection. Beat in the operation of the road is rough cars, poor load changes or two assembly installed, can make the gearbox output shaft and the Angle between the drive axle of main reducer input shaft and the distance change, so in the form of universal joint drive a car powered with double universal joint, is to have a universal joint on both ends of the transmission shaft, its role is to make the shaft ends of equal Angle, so as to ensure the instantaneous angular velocity of the input shaft and output shaft are always equal.

Fig. 4.4:Universal Joint

4.4 Rear Wheel Drive

'To every action there is an equal and opposite reaction' This statement means that every component that produces or changes a torque will also exert an equal and opposite torque tending to turn the casing. For example, when the engine crankshaft exerts a torque in a clockwise direction, the cylinder block will tend to rotate in an anticlockwise direction.

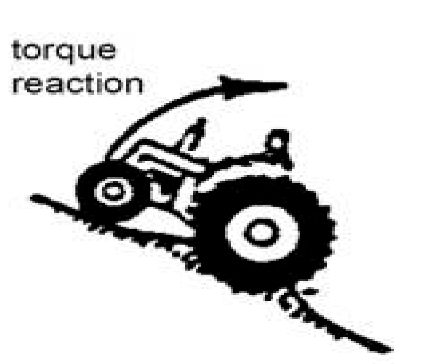

Fig. 4.5: Rear Wheel drive of a Tractor

A further example of torque reaction is shown in which a tractor with its rear driving wheels locked in a ditch. In this situation the driver must be careful, because torque reaction is likely to lift the front of the tractor rather than turn the rear wheels.

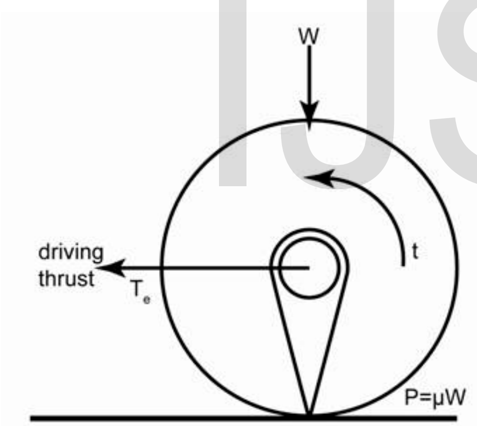

Fig. 4.6: Lever action of wheel

When the law stated above is applied to rear axles, you will see that some arrangement must be provided to prevent the axle casing turning in the opposite direction to the driving wheels.

4.5 MOTOR

Permanent Magnet Brush Less DC (PMBLDC) motors are a kind of synchronous motor. This indicates the magnetic field produced by the stator and the magnetic field produced by the rotor twirls at the same frequency. PMBLDC motor is built with a permanent magnet rotor and wire wound stator poles.

Stator: The stator of a PMBLDC motor as shown in Fig4.7 comprises of stacked steel laminations with windings kept in the slots that are axially cut along the inner periphery. Most PMBLDC motors have three stator windings linked in star fashion. Each of these windings is assembled with various coils interconnected to derive a winding. One or more coils are kept in the slots and they are interconnected to form a winding. Each of these windings is distributed over the stator periphery to form an even numbers of poles.

Fig. 4.7: Stator of a PMBLDC motor

Rotor: The rotor is formed from permanent magnet and can alter from two to eight pole pairs with alternate North (N) and South (S) poles. The suitable magnetic material is selected to form the motor depending upon the required field density in the rotor. Ferrite magnets are used to make permanent magnets. Now a day, rare earth alloy magnets are gaining popularity.

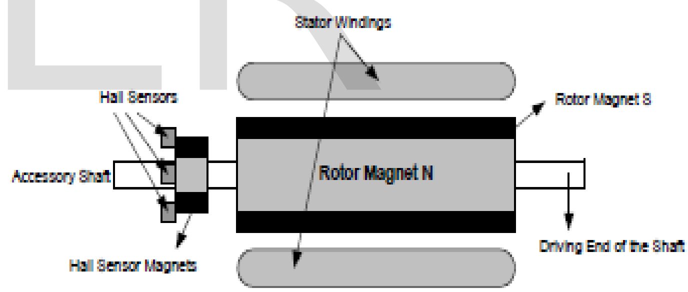

Fig. 4.8: Rotor and Hall sensors of PMBLDC motor

Hall Sensors: In order to rotate the PMBLDC motor, the stator windings ought to be energized in an order. It is essential to understand the rotor position in order to know which winding will be energized following the energizing sequence. Rotor position is perceived using Hall effect sensors embedded into the stator on the non-driving end of the motor as shown in fig4.8.

Theory of operation: Each commutation sequence has one of the windings energized to positive power, the second winding is negative and the third is in a non-energized condition. Torque is engendered because of the interaction between the magnetic field generated by the stator coils and the permanent magnets.

Commutation Sequence: Every 60^0 of rotation as shown in Fig., one of the Hall sensors changes the state. It takes six steps to finish an electrical cycle. In Synchronous, with every 60^0, the phase current switching ought to be renovated. The number of electrical cycles to be repeated to complete a mechanical rotation is dictated by the rotor pole pairs. One electrical cycle is completed for each rotor pole pairs.

PMBLDC has the merits of simple structure, high efficiency, electronic commutating device, high starting torque, noiseless operation and high speed range, etc. Hence, the motor has been widely used. Their application is however based on the assumption that the change in speed and load occurs very slowly. The high torque-weight ratio of PMBLDC motors makes it very suitable for applications such as electric vehicles. The BLDC motors have many benefits over DC motors and induction motors.

5 FABRICATION

Fig .5.1: Fabricated chassis with C cross section

Fig.5.2: Chassis with rear assembly

Fig. 5.3: Design with chassis, rear assembly & motor with gear box

Fig. 5.4: Fabrication with tyres & Front handle

Fig. 5.6: Fabrication with Front covering

Fig. 5.5: Fabrication with top structure

Fig. 5.7: Vehicle with finished mechanical structure

Fig. 5.8: Completed Vehicle

6. RESULT SUMMARY

Motor Specifications: **Permanent Magnet Brushless DC motor with hall sensors 3kWatts, 48V, 3000RPM**

Gear Box: **1:15**

Vehicle Speed: **20kmph**

Results are tabulated in the table, when the pressure load of 1.73N/cm^2, young's modulus 130Mpa, poisons ratio in between 0.2-0.3 and density is 0.0078N/cm^3 for cast iron material.

Table 5.1: Stress results

No	Type	Stress intensity (Mpa)	Von mises stresses (Mpa)	Total deformation (mm)
1.	I-type cross section	65.21	58.90	0.0001538
2.	C-type cross section	62.58	58.60	0.0001676

Based on the results the chassis was fabricated with cast iron and type of cross section is C

7 CONCLUSION

After observing the all results and comparing the I and C type cross sectional cast iron chassis frames, it is concluded that C-type section is better when a comparison is made for von mises stress andtotal deformation. So from the above values and based on the manufacturing cost, stresses induced in the chassis, strength of the chassis, it is better to consider the C-type cross section. Hence fabrication of chassis is done with C-type cross section with cast iron material**.**

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